

# An Ontological Perspective on Surgical Procedures

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*We studied terminological phrases on surgical procedures — from coding systems, controlled vocabularies, textbooks, and medical records — by an ontological point of view.*

*A surgical procedure can be accurately described only by a set of sentences, in textbooks or surgical reports; a terminological phrase is just a short synthesis of that description.*

*We outline three points of view actually used to construct a phrase, based on i) relevant phases and variants; ii) focus on structures, functions and pathologies; iii) evolution of information and decisions during the process of care.*

*For each of them we discuss potential principles and mechanisms, with the aim of deriving guidelines to generate homogeneous systematic names, to organize regularities in classifications and nomenclatures, to normalize expressions in formal languages.*

## INTRODUCTION

Diffusion of clinical information systems shifted application of terminological systems (e.g. classifications and nomenclatures) from statistics to medical record, i.e. from off-line use to routine on-line multiple uses, including support to care provision and health care organization<sup>11, 14, 17</sup>.

Advanced terminological systems are required, providing adequate representation of terminological phrases within computer systems<sup>15</sup>.

This paper deals with terminological phrases on surgical procedures. Phrases may be eventually organized in a family of coherent terminological systems to be applied in various situations (e.g. scheduling, reporting, reimbursement, cost analysis). The development of such systems is a goal of the GALEN-IN-USE project<sup>◇</sup> where the present study is being performed.

*Full description vs terminological phrases.* The proper description of a surgical procedure — in a textbook or in a surgical report — consists of several sentences<sup>6</sup>. For various uses of management and communication, specialists reduce that description to

a terminological phrase; selected details are made explicit according to purpose and context. From that phrase and its context, "receiving" specialists disambiguate among sub-activities and reconstruct a set of *typical* features:

- operational factors (i.e. way to perform the various phases);
- decisional factors (i.e. motivation for the procedure and for its variants);
- organizational factors (i.e. usage of resources);
- benefits and problems for the patient.

Therefore, details evoked by a phrase in skilled humans go beyond the juxtaposition of meanings of words in that phrase; computer-based exploitation of nomenclatures requires to make explicit at least a part of this knowledge.

*Term vs terminological phrase.* Phrases in routine communication and terminological systems for health care are not the usual "terms" from terminology theories<sup>4, 6</sup>: in fact, they are "motivated" expressions — pragmatically created by users according to language rules — that specify the amount of details adequate to trigger clinical, administrative, or scientific applications (e.g. in tables used to schedule use of resources or to ask for reimbursement).

## MATERIALS AND METHODS

We studied phrases both from coding systems (ICD-9-CM<sup>8</sup>, MeSH<sup>10</sup>, SNOMED<sup>18</sup>, ICPM<sup>19</sup>, CPT<sup>1</sup>; examples from HCIMO<sup>5</sup>, CDAM<sup>9</sup>, OPCS<sup>12</sup> provided by the team preparing CEN ENV 1828<sup>3</sup>) and from various sources (surgical textbooks, local controlled vocabularies, medical records, and weekly plans for operating rooms available at the IV Surgical Clinic of University "La Sapienza", Roma).

Our aim was to discover (and to document with examples) principles and mechanisms to construct more systematically terminological phrases and their computer-based representation.

Most of the work was carried out informally; phrases were compared across hierarchies (when available) to search for similar or complementary constructs; entries of controlled vocabularies were compared with corresponding rubrics in coding systems.

Formalism and tools of GALEN-IN-USE were used to test the approach: three independent specialist teams analyzed — under the supervision of the Authors and according to the guidelines proposed in

<sup>◇</sup> information and documents on the GALEN-IN-USE project (formerly GALEN) — funded by European Union in the Health Care Telematics Programme — is available at <http://www.cs.man.ac.uk/mig/galen> or by e-mail from [galen@cs.man.ac.uk](mailto:galen@cs.man.ac.uk)

this paper — a set consisting of 165 rubrics from ICD-9-CM (in cardiovascular and proctological domain) and of 54 rubrics from a local list of laparoscopic procedures.

We considered also the European Pre-standard CEN ENV 1828<sup>3</sup> and a report about ICD-10-PCS<sup>2</sup>.

## RESULTS

We identified three major points of view — partially overlapping in practice — used in the construction of terminological phrases:

- i) relative importance of phases and variants;
- ii) focus on structures and substances, functions or pathological processes;
- iii) evolution of information and decisions about the procedure, during the process of care.

We will see in the Discussion how each point of view influences a possible effort for systematization.

### Relative importance of phases and variants

Every organized human activity can be subdivided in phases: preparation, initial phase, main phase, final phase, follow-up; each phase can have variants and can be divided in turn in sub-phases; phases can be partially or totally overlapped. Accurate representation and management of activities (and of their context) is performed by appropriate tools, as narrative descriptions, protocols, flow-charts.

Mutual relevance of each phase in the whole process determines which phases are used to construct the phrase that will shortly designate an activity.

Usually an activity is designated by its main phase only, because the latter implies a precise way to perform the other phases, or because variants may be considered as irrelevant. In this case the same expression has two senses: the proper one (as main phase) and the extended one (as the whole).

But often a variant heavily affects usage of resources or consequences on patient. Therefore minor phases appear in the designation, in addition to main phase: we found phases related to *approach* (e.g. re-sternotomy, that presents high risks), to *severe intraoperative situations* (e.g. cardiopulmonary bypass), to *usage of expensive devices* (e.g. disposable staplers, for suture in minimally invasive surgery), to *post-operative consequences* (e.g. colostomy in Hartmann operation influences comfort of the patient and planning of post-operative stay).

### Number of phrases and codes for a procedure.

Phases can be expressed by independent phrases, or by modifications of another phrase; also the actual number of codes in a given coding system is a design choice. In fact, sometimes a phase deserves a phrase with its own particular code, e.g. "heart massage" in MeSH E4.752, "aspiration of bone marrow from

donor for transplant" (ICD-9-CM 41.91) or "ventriculographie per-opératoire" (CDAM F148); sometimes complex phrases correspond to a single code, as in: "thoracotomy...with cardiac massage" (CPT 32160); or "endarterectomy with temporary bypass during procedure" (ICD-9-CM 38.1).

### Focus on structures, functions or processes

A surgical procedure typically contrasts a pathological process. Surgeons manipulate physical objects (body parts, substances, or devices), to alter their morphology, to restore or partially fix damaged functions, or to induce reactions from the organism.

*Levels of interpretation.* Surgeons — in similar situations — can focus on the structure involved, on the body function they intend to alter directly (e.g. revascularization) or indirectly (e.g. a process of sclerosis triggered by injection), or on the pathological process they are facing or preventing.

In other words, to designate a procedure, speakers can generate terminological phrases with a variable amount of interpretation, e.g.

1. 'relocation' of mammary artery
2. coronary artery shunt
3. myocardial revascularisation
4. heart surgery (i.e. surgery dealing with heart-related pathologies)

In fact, speakers can construct phrases according to different levels of abstraction (see also Discussion):

- L1. no apparent interpretation (e.g. cut, insertion);
- L2. topographical / morphological interpretation (e.g. drainage, shunt );
- L3. functional interpretation (e.g. revascularisation );
- L4. pathological explanation, e.g. evoking explicitly a <disease>, or a damaged <body structure> .

The same surgical procedure may be expressed at one or more levels; sometimes the speaker does not specify the actual way to perform the procedure: e.g. "heart revascularization" may be performed according to various techniques, "control of postoperative hemorrhage of anus" (ICD-9-CM 49.95) may even involve non-surgical actions.

*Constructs depend on focus.* Most activities using devices may be considered by two points of view; e.g. the phrase "insert 2 pins in femur" focuses on device (pin) and expresses a simple act (insert); the phrase "repair femur with 2 pins" focuses on the body location (femur) and expresses a purposive action (repair); the device becomes a means. It would have been possible also to focus on the medical ground (e.g. a fracture).

The verb (or the "deverbal noun") used by the speaker depends on the focus; phrases produced in this way may be very similar and the different constructs are often transformable into each other.

We encountered various kinds of contrasts, e.g.

- direct target (remove a tear) vs morphological outcome (smoothing a surface);
- substance (inject neurolytic fluid) vs functional goal (destroy a nerve by neurolytic fluid);
- required function on structure (release bowel, revascularization of heart) vs deed on its context (respectively: lyse peritoneal adhesions, aorto-coronary bypass);

*Use of levels in actual terminological systems.* Most terminological phrases in the rubrics of coding systems we studied are constructed around L2 or L3 above. Perhaps L1 is too poor to represent a whole procedure, and is normally transformed into <means> of an L2 or L3 procedure; L4 is too generic and is considered as <context> or <medical ground>.

In the organisation of hierarchies, higher levels are used to cluster concepts based on more immediate descriptions; e.g. in MeSH E4.752.376, "heart surgery" (L4) is superordinate to "myocardial revascularisation" (L3) and the latter is superordinate to "aortocoronary bypass" (L2).

Titles of chapters in the analyzed surgical textbooks reflect target structures and related pathologies (L4).

#### **Evolution of information and decisions about a procedure**

A surgical procedure is embedded in the care process. Amount and quality of information about a procedure — to be performed or already performed — varies with evolution of the care process and is mirrored in correspondent phrases.

Moreover, phrases should satisfy administrative, organizational, and clinical purposes.

In the example below the emphasis shifts gradually from the pathological process to the goal, and then to the actual procedure performed (with different details):

- **admission:** "*operation for lower third rectum cancer*" (the operational diagnosis implies a set of generic previsions in terms of related procedures);
- **scheduling:** "*low anterior resection of rectum or abdominoperineal amputation of rectum (Miles operation)*" (some diagnostic and decisional phases may be planned and performed intra-operatively; in this case two possible operations are prepared, one of which will be actually performed);
- **reporting:** "*low anterior resection of rectum with double stapling technique*" (the phrase denotes the three main features: the *low* resection, the *anterior* approach and the *anastomotic* technique);
- **discharge:** "*other anterior resection of rectum*", ICD-9-CM 48.63 (the classification groups different possible technical solutions all together);
- **reimbursement:** "*operation for rectum cancer*", DRG147 (this DRG focuses just about disease and

location; in other cases DRG introduces also the concept of minor/major operation);

- **cost analysis:** "*anterior resection of the rectum with double stapling technique*" (the use of two staplers is a remarkable item of cost);
- **quality assurance:** "*low anterior resection of rectum without temporary colostomy*" and "*operation for lower third rectum cancer*" (creation of a protective temporary colostomy is an important indicator on quality of life of the patient, while the pathological process is a useful key for outcome evaluations).

## **DISCUSSION**

### **Need for computer-based terminological services**

Paper-based terminological systems cannot satisfy increasing needs of computer-based processing: integration, support of multiple views, re-use of data. New terminological systems — conceived specifically for computer use — will dynamically represent details and will be easily mappable one to the other; they should be based on a compositional approach using predefined descriptors.

If each phrase in a given field corresponds to a unique sequence of descriptors linked by semantic relations, that sequence may be used to build systematic names (motivated terminological phrases built according to predefined rules) and, with further normalization and additional rules, to build a canonical form for automatic classification and matching<sup>13, 14, 15</sup>.

*The European approach to terminological standards in health care.* The European Standardization Committee (CEN) is developing standards to support the above compositional approach, by organizing descriptors into categories and describing semantic links and rules to combine categories in a given field<sup>4, 16</sup>. Given a set of nomenclatures, an effective achievement could be to store in a processable format the representation of each phrase by descriptors selected from a "system of descriptors" (i.e. from an intermediary thesaurus — *inter-thesaurus* — in principle independent from source corpora)<sup>16</sup>.

This approach also supports maintenance and browsing of individual terminological systems, by allowing dynamic arrangement of phrases according to different criteria, to satisfy different purposes.

It provides a background for translation of phrases into different languages, semi-automatic coding (including search for classes which could apply for a particular individual) and indexing.

Specialists can use descriptors and semantic links to create (and communicate) new expressions, or they can introduce additional descriptors, being responsible for the correctness of the result.

The European Prestandard on surgical procedures (CEN ENV 1828<sup>3</sup>) requires that terminological

phrases in coding systems contain explicit reference to at least an action (the surgical deed) and an anatomical location. Optionally they may refer also to a device (surgical equipment) and a pathological structure (pathology). Combinatorial rules to produce sensible phrases from descriptors are also provided. Nevertheless the standard does not specify rules to normalize the three points of view here described.

*Formal models.* A further generation of systems is also appearing: formal models, as in GALEN-IN-USE. With respect to the CEN approach, they are parsimonious (by using a generative engine), are able to model "all and only" the sensible concepts, and provide (automatic) validation capability.

But development of a robust formal model is more expensive and resource consuming than building just the structured representations of a given list of phrases by descriptors; in particular, severe problems of coherence and style appear in a large model; the CEN approach could be an useful intermediate step.

Precise normalization strategies must be defined, to enable: classification of phrases at different levels of interpretation, recognition of similarities and overlaps between phrases based on different number of phases, as well as (automatic) generation of sensible phrases with control of interactions among all the details potentially interesting for different purposes.

### Ontological normalization

Long-term systematization of terminological phrases, for routine medical use, could be appropriate, but initially a low users' compliance could be expected.

The *internal* representation for computer use should enable present applications to manage the "meaning" behind each phrase and facilitate matching and classification: implied details should be made explicit and phrases should refer to homogeneous descriptors and be structured in a coherent way.

Automatic transformation from and to the different points of view seems feasible, i.e. systematic and reversible, provided that enough information is preserved, restored and correctly represented.

Normalization based on ontological principles, i.e. on paradigms of conceptual organization<sup>7</sup>, can avoid unnecessary dissimilarities; it can be performed:

- by the surgeon, during generation of a phrase (specially if suitable computer interfaces are available to facilitate structured data entry), or
- by computer, transforming a representation by suitable rules (with or without information loss), or taking the risk of adding presuppositions from co-text (using inheritance or defaults, or exploiting similarity with analogous concepts);
- by experts that analyze corpora on surgical procedures, to produce a systematic representation, or systematic intensional definitions to be translated into a formal model (e.g. in GALEN-IN-USE).

### Style guidelines

We suggest below ways to partially "neutralize" each point of view. They fosters uniform interpretations — compatible with ENV 1828<sup>3</sup> and ICD-10-PCS<sup>2</sup> — to drive distributed systematization activities.

*Relevance of main phase.* Some normalization is possible, by representing similar operations in a similar systematic way, i.e. making explicit phases that will facilitate homogeneous computer processing. Eponyms, efficiently used to evoke a variant involving a specific sequence of actions, may be normalized by making explicit the most relevant phases of the operation.

*Focus on structure.* Computer-based processing should support appropriate systematic transformations into a unique preferred form, whenever appropriate.

We decided to try to identify, in each phrase, the different kinds of processes according to the L1-L4 schema above, and to use as far as possible representations and systematic names constructed according to the following frame, built on a "normalized" perspective:

- L2 purposive action performed on body structures
- L1 through simple act using devices, substances or grafts
- L3 to induce a body process, with direct or induced functional effects on body structures
- L4 motivated by a care process to contrast the underlying pathological process.

i.e. taking in preference L2-process as the head, and transforming — when present — L1-process into a "less interpreted" act related to means, L3-process into body process related to functional effects to be achieved by the procedure, L4-process into a care process (including prevention) related to motivation.

Consider for example "balloon angioplasty of single coronary vessel" in ICD-9-CM: it is an *inclusion* in 36.01 about PTCA in the context of 36.0 "removal of coronary artery obstruction".

We can take as head the effect on structure (L2 dilatation of artery); the act on device (L1 insertion of balloon catheter) becomes instrumental to that head, while fixing the problem (L4 correction of stenosis of artery) is restored and rendered as motivation.

Here the L3-process was not explicit and that slot is not used; the other details that were explicit in the phrase will be hooked where appropriate.

*Evolution of the process of care.* Evolution implies a drift across the above levels of interpretation, to represent the current status of information about a procedure, but a certain amount of coherence can be maintained between the different expressions.

Normalization of the expressions along this axis is partially possible, using the frame just described.

## CONCLUSIONS

This paper experimentally derives guidelines to organize and normalize concepts on surgical procedures. Guidelines have to be consolidated through analysis of a larger sample: this test is currently being performed in Rome by the partners within the GALEN-IN-USE project.

The methodology applies to every topic where there is a need to facilitate maintenance, rationalisation and spontaneous convergence of existing nomenclatures into an integrated terminological system and to provide advanced terminological services.

The management of medical semantics is a key issue of clinical information systems. Suitable computer-based terminological systems allow to *represent* the needed level of details on clinical cases (as opposed to *classify* them) or to cluster them dynamically, according to varying user's needs. Multiple uses of data, with appropriate conversion, are theoretically possible, based on integration of coherent coding systems in the same information system.

Availability of terminological services will support massive acquisition and integration of knowledge:

- to link (automatically) knowledge bases to medical record in an Intelligent Information System,
- to extract knowledge from medical records and books;
- to compare and merge knowledge from different sources.

The ontological approach addresses the heterogeneity among paradigms of knowledge organization and thus enables knowledge sharing and integration.

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## References

1. American Medical Assoc. *Physician's Current Procedural Terminology (CPT-4)*. AMA 1989
2. Averill RA, Mullin RL, Steinbeck BA, Goldfield NI, Grant T. The development of the ICD-10 Procedure Coding System (ICD-10-PCS). available from: 3M Health Information Systems, 100 Barnes Road, Wallingford CT 06492.
3. CEN ENV 1828:1995. Medical Informatics — Structure for classification and coding of surgical procedures. Brussels, 1995
4. CEN ENV 12264:1995. Medical Informatics — Categorical structure of systems of concepts — Model for representation of semantics. Brussels, 1995
5. Centre for Medical Informatics, Université Catholique de Louvain. *Adaptation hospitalière de la classification internationale des maladies et des opérations (HCIMO)*. Brussels, 1990
6. Galeazzi E, Agnello P, Gangemi A (et al). What is a medical term ? Terms and phrases in controlled vocabularies and continuous discourses. In: Barahona P, Veloso M, Bryant J (eds) : *Proceedings of the 12th Congress of the European Federation for Medical Informatics*, Lisbon, 1994, 234-239
7. Steve G, Gangemi A, Rossi Mori A. *Knowledge integration of medical terminological sources: an ontological mediation*. In: Stewman JH (ed) *Proc of the 9th Florida AI Research Symposium*, Eckerd College, St. Petersburg, FL 1996: 321-8
8. Health Care Financing Administration, U.S. Department of Health and Human Services. *International Classification of Diseases, 9th rev. Clinical Modifications (ICD-9-CM)*, vol. 3 - *Procedures*, 3rd edition, DHHS-HCFA, 1988
9. Ministère des Affaires Sociales et de la Solidarité. *Catalogue des Actes Médicaux (CDAM)*. Paris, 1991
10. National Library of Medicine. *MeSH Medical Subject Headings*. Bethesda, MD: NLM (yearly)
11. Nowlan W, Rector A, Rush T, Solomon W. From Terminology to Terminology Services. 18th Annual Symposium on Computer Applications in Medical Care (SCAMC94). Washington DC, 1994: 150-154.
12. Office of Population Censuses and Surveys. *Classification of surgical operations and procedures. 4th revision consolidated version 1990 (OPCS-4)*. Her Majesty's Stationery Office, London, 1990
13. Rector A, Gangemi A, Galeazzi E, Glowinski A, Rossi-Mori A. The GALEN CORE Model Schemata for Anatomy: Towards a re-usable application-independent model of medical concepts. In: Barahona P, Veloso M, Bryant J (eds) : *Proceedings of the 12th Congress of the European Federation for Medical Informatics*, Lisbon, 1994, 229- 233.
14. Rector A, Glowinski A, Nowlan W, Rossi-Mori A. Medical concept models and medical records: An approach based on GALEN and PEN&PAD. *Journal of the American Medical Informatics Association* 1995;2(1):19- 35.
15. Rector A. Compositional models of medical concepts: towards re-usable application-independent medical terminologies. In: Barahona P, Christensen JP eds. *Knowledge and Decision in Health Telematics*. Amsterdam: IOS Press, 1994; 109-14
16. Rossi Mori A, Galeazzi E, Agnello P, Steve G. *Terminological modelling in CEN/TC251/WG2 and GALEN: the example of surgical procedures*. in the Proceedings of the AMICE 95 Conference: Strategic alliances between patient documentation and medical informatics, Amsterdam, 1995
17. Rossi Mori A. Coding systems and controlled vocabularies for hospital information systems. *Int J Biom Comp* 39 (1995) 93-98
18. Rothwell DJ, Coté RA, Brochu L (eds), *SNOMED International*, Northfield, IL: College of American Pathologists, 1993, 3rd ed.
19. World Health Organisation. *International Classification of Procedures in Medicine (ICPM)*. Geneva: WHO, 1978